Mini-CLEAN

Dan McKinsey
Yale University

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Homestake Workshop

Mini-CLEAN Collaboration

Yale University: M. Harrison, W. H. Lippincott, D. N. McKinsey (spokesperson), J. Nikkel

Los Alamos National Laboratory: A. Hime, D. Mei, L. Rodriguez, K. Rielage, L. Stonehill

National Institute for Standards and Technology: K. J. Coakley

Queen's University: M. Boulay

Boston University: D. Gastler, E. Kearns

Mini-CLEAN goals

Above ground (2006-2007):

Validation of the long-term performance of PMTs at low temperatures.

Efficient collection of the scintillation light with immersed PMTs.

Purify liquid neon and liquid argon to remove contaminants that absorb scintillation light or contribute radioactive background.

Particle identification via scintillation pulse timing.

Measurements of scintillation absorption and scattering

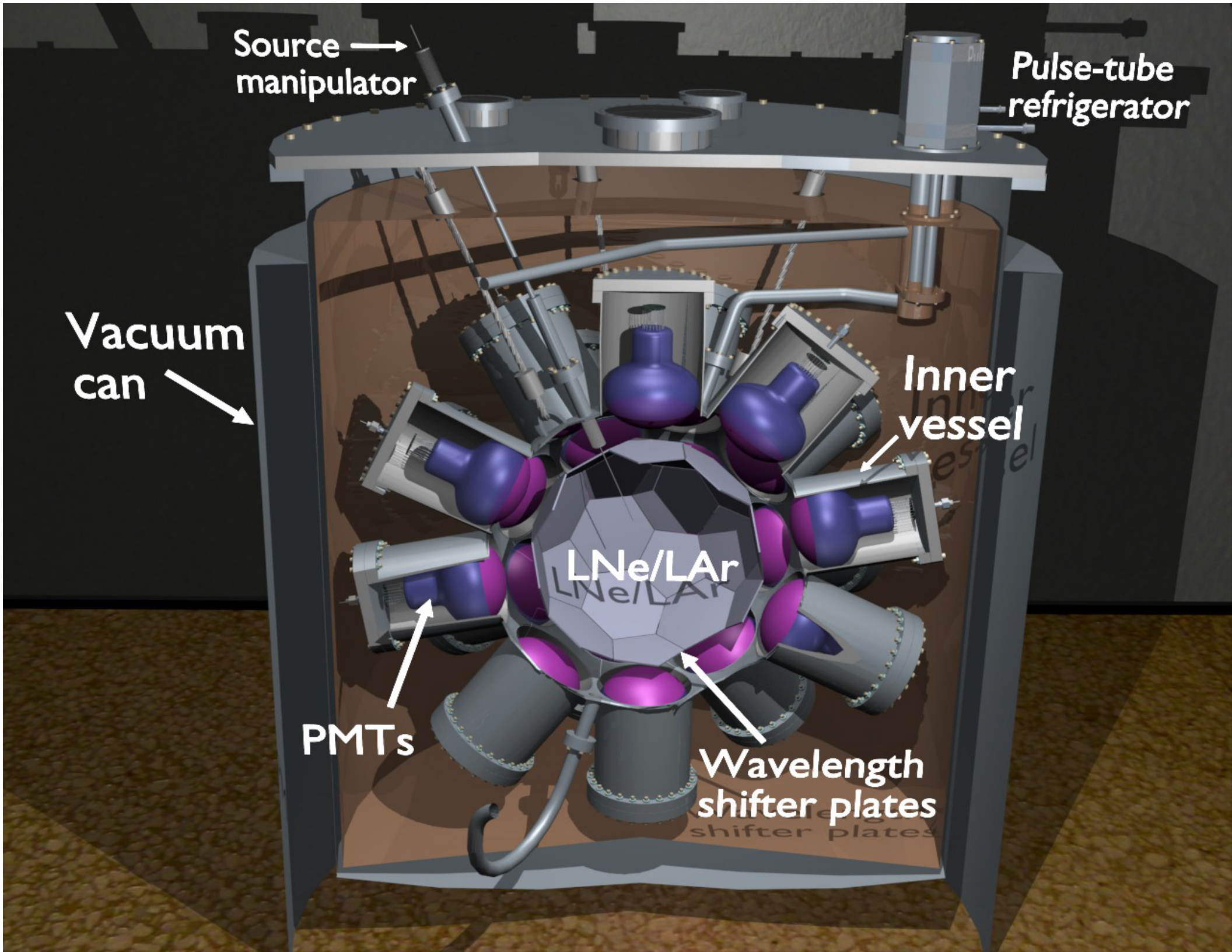
Demonstrate position reconstruction using the PMT hit pattern.

Below ground (2008-2009):

Fill mini-CLEAN with LAr, search for WIMPs with sensitivity of 10^{-45} cm^2 at 100 GeV.

Replace LAr with LNe, independently measure gamma and fast neutron backgrounds.

Demonstrate low-background capabilities of LNe for future 10-100 ton CLEAN detector


Source manipulator
Pulse-tube refrigerator
Vacuum can
Inner vessel
LNe/LAr
PMTs
Wavelength shifter plates

Liquid Neon:

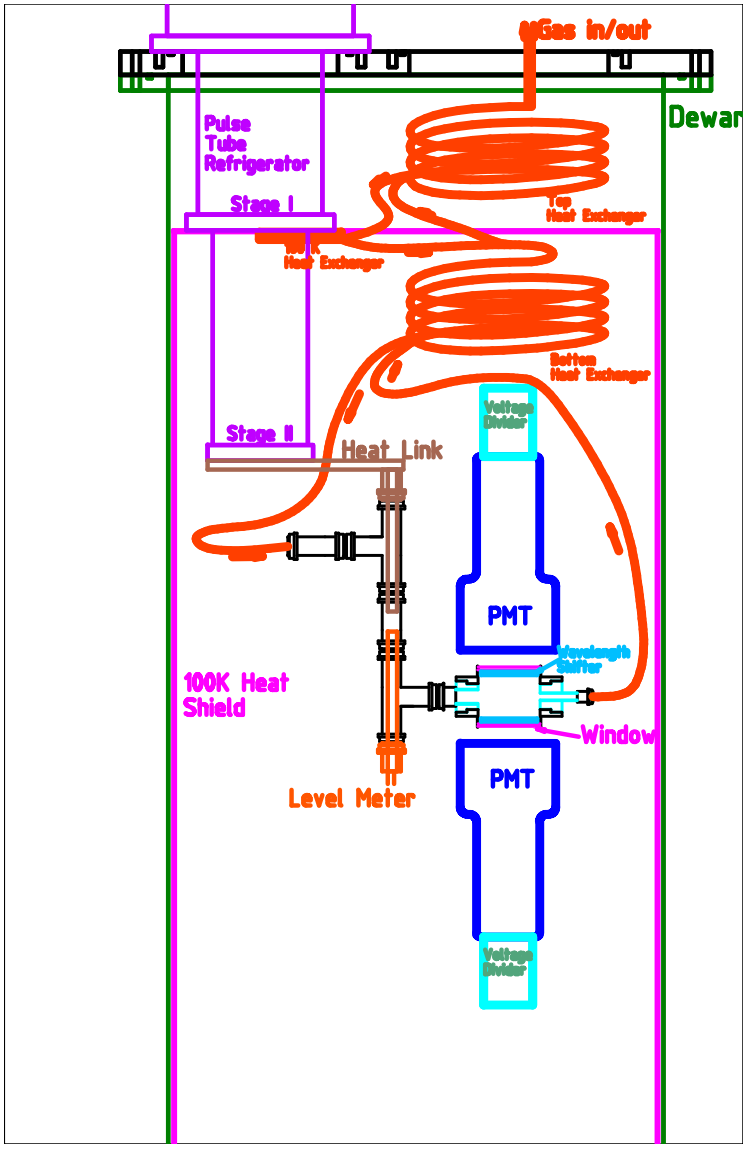
Density of 1.2 g cm^{-3}
Scintillation centered at 80 nm
No long-lived isotopes (radiation free!)
Suitable for a 10-100 ton solar neutrino detector (CLEAN)
(Roughly) 30,000 photons/MeV
A = 20

Liquid Argon:

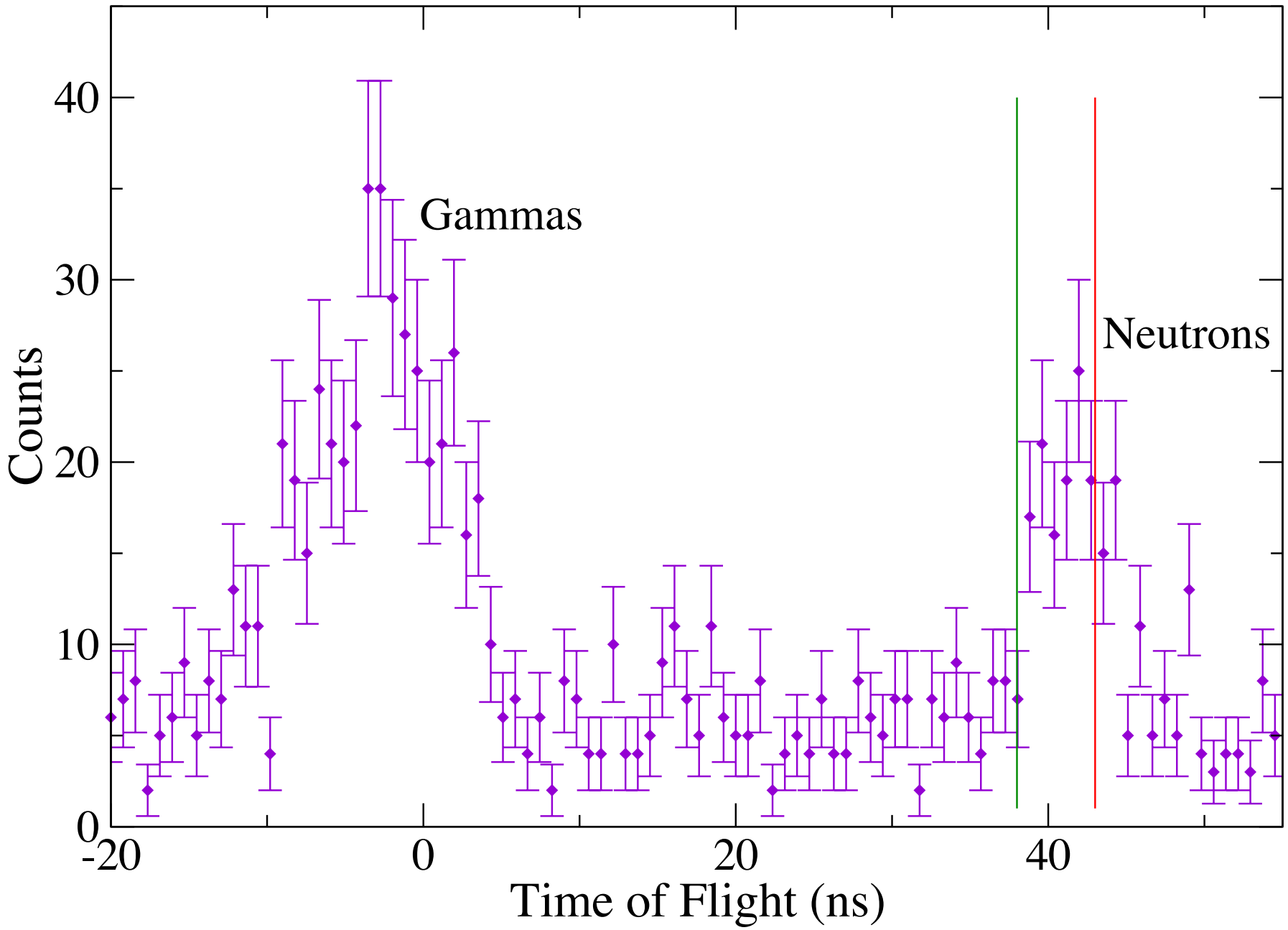
Density of 1.4 g cm^{-3}
Scintillation centered at 128 nm
Has internal background: Ar-39 at 8E-16 concentration (1 Bq/kg)
Increasingly promising for WIMP dark matter search
40,000 photons/MeV
A=40

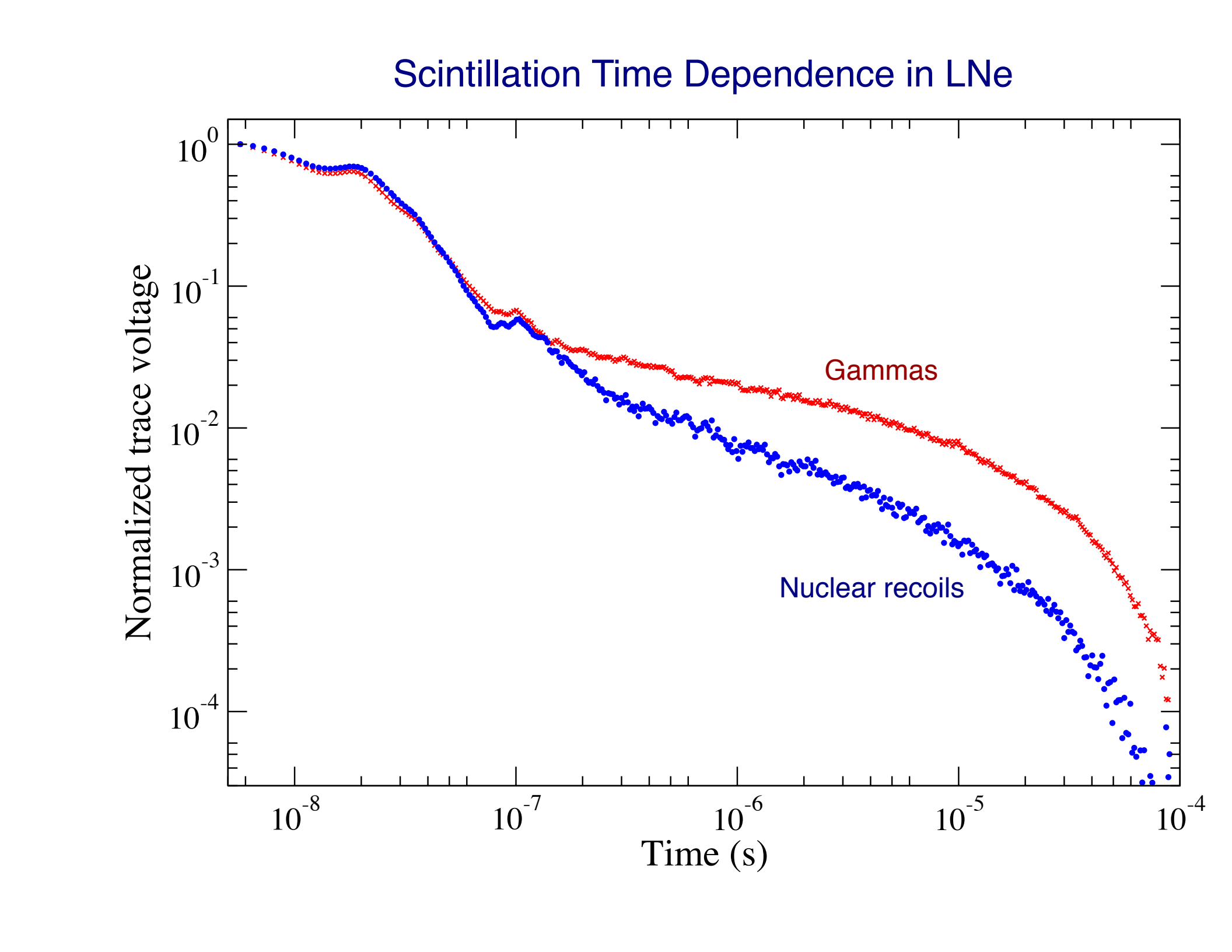
Both liquids show good pulse shape discrimination (PSD)

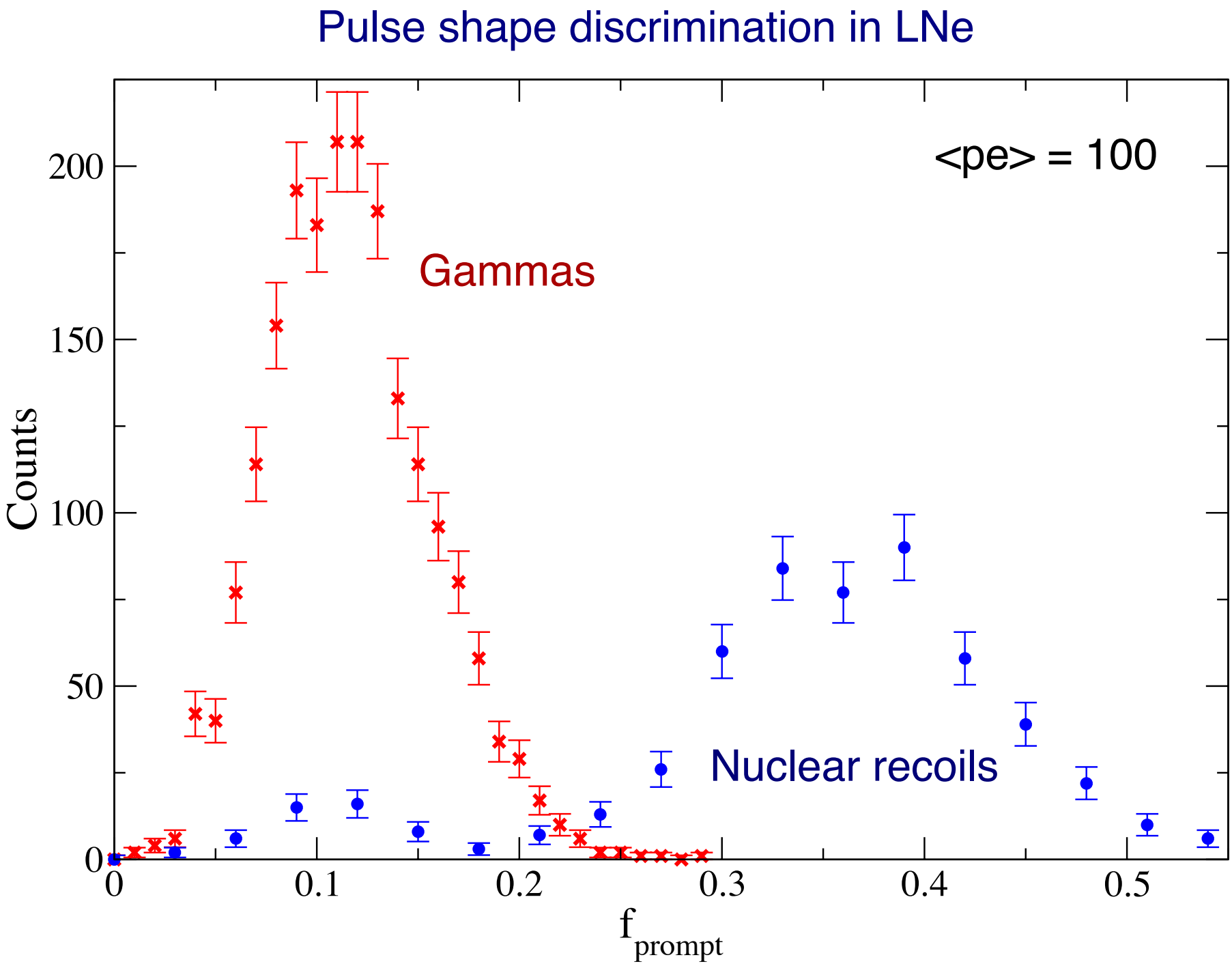
Pico-CLEAN at Yale

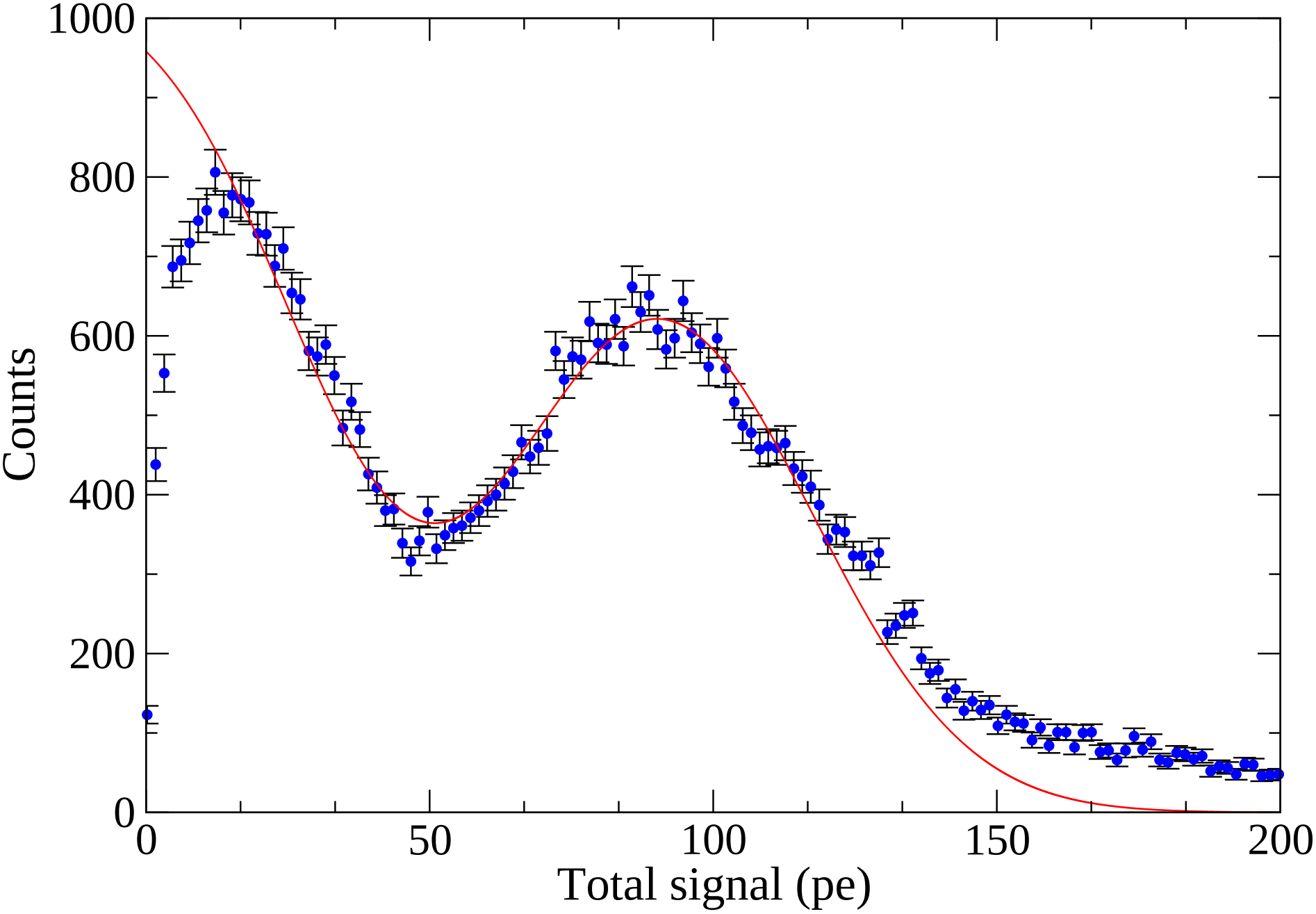


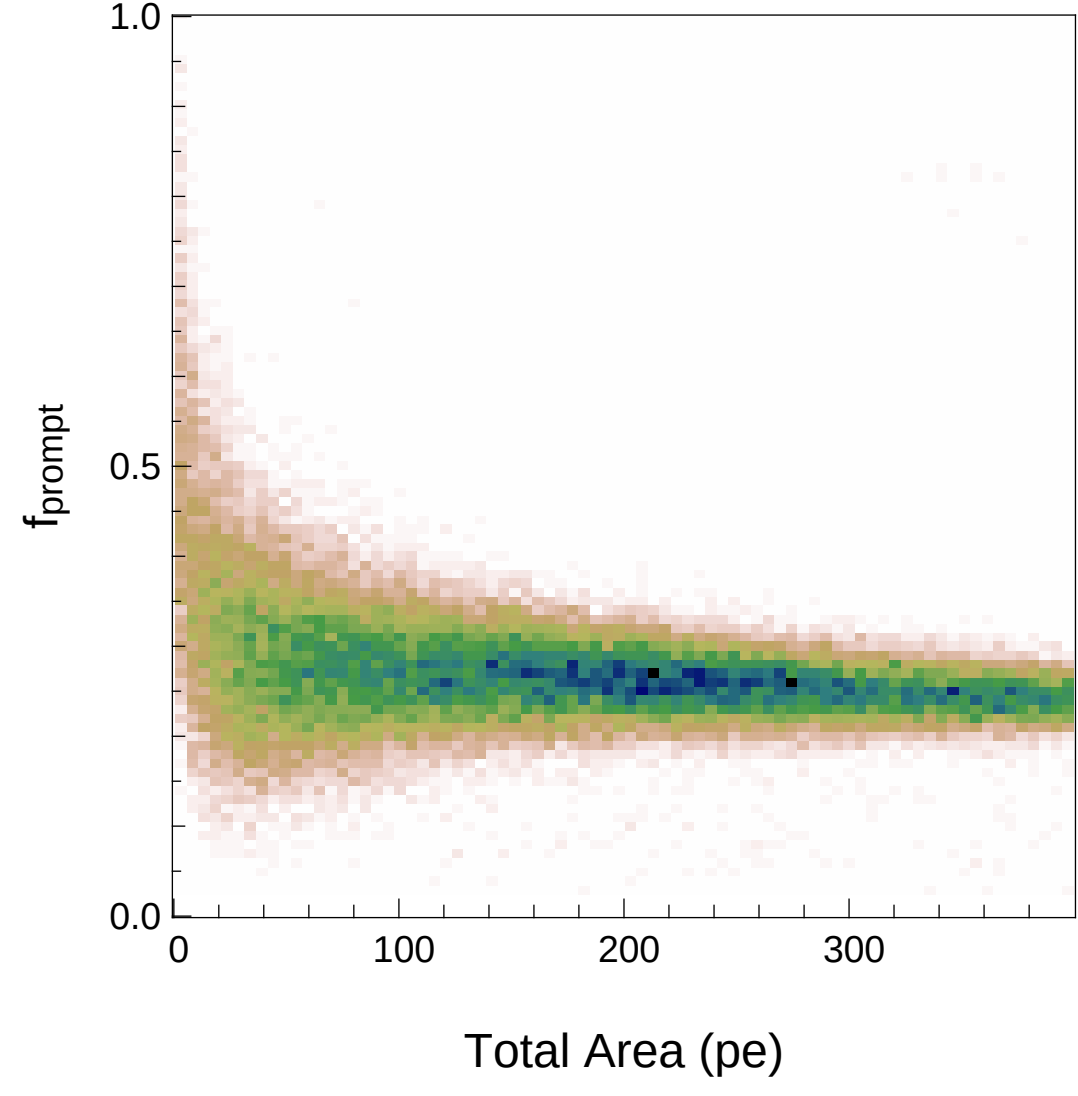
Neutron generator at Yale (2.5 MeV, 10^6 n/s)

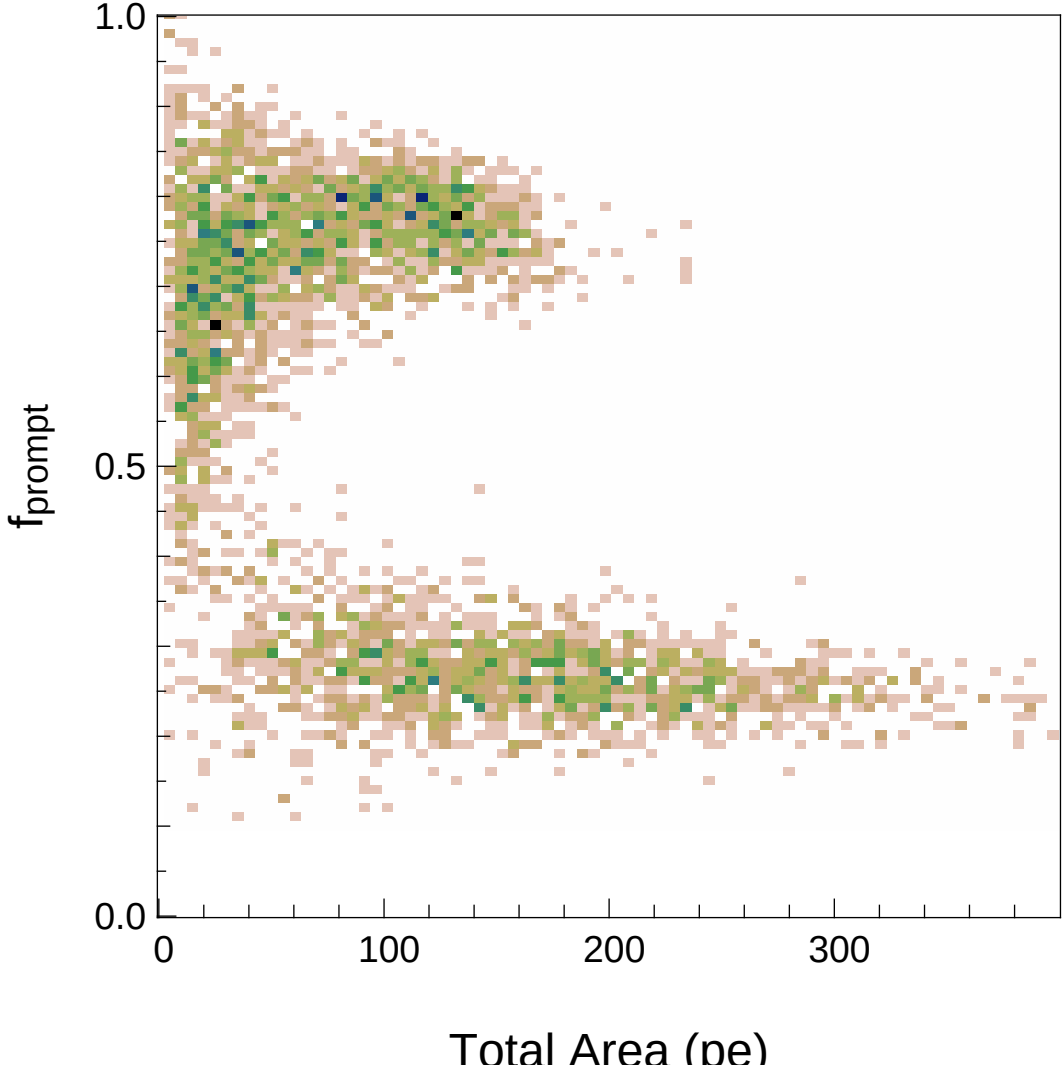

Gammas
Neutrons
Counts
Time of Flight (ns)
0
10
20
30
40
-20
0
20
40


Scintillation Time Dependence in LNe
Normalized trace voltage
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
Gammas
Nuclear recoils
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
Time (s)

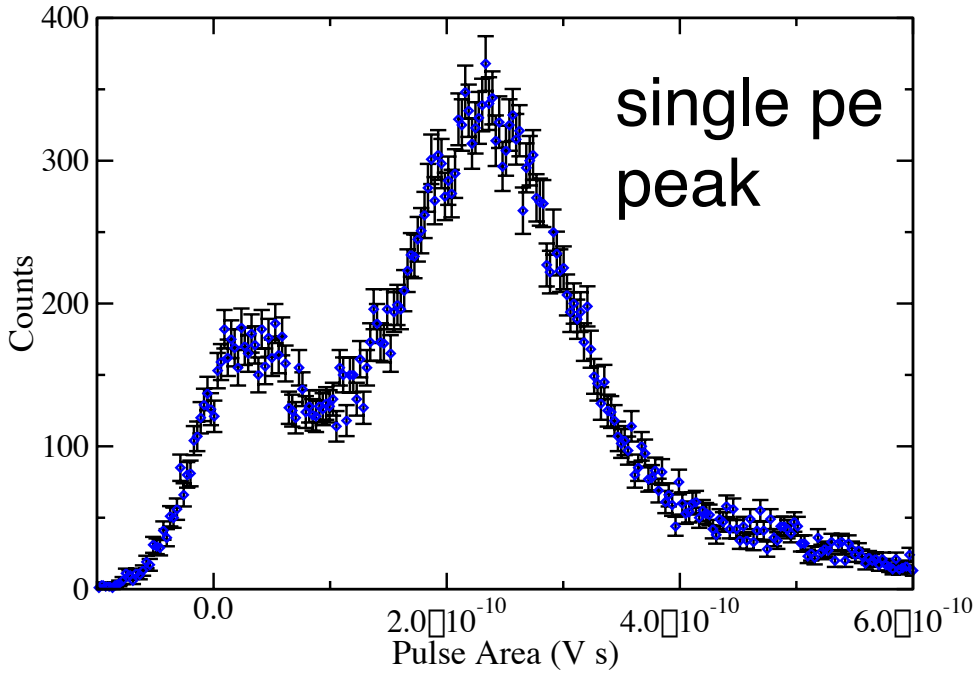

Pulse shape discrimination in LNe
<pe> = 100
Gammas
Nuclear recoils
Counts
f prompt
0
50
100
150
200
0
0.1
0.2
0.3
0.4
0.5

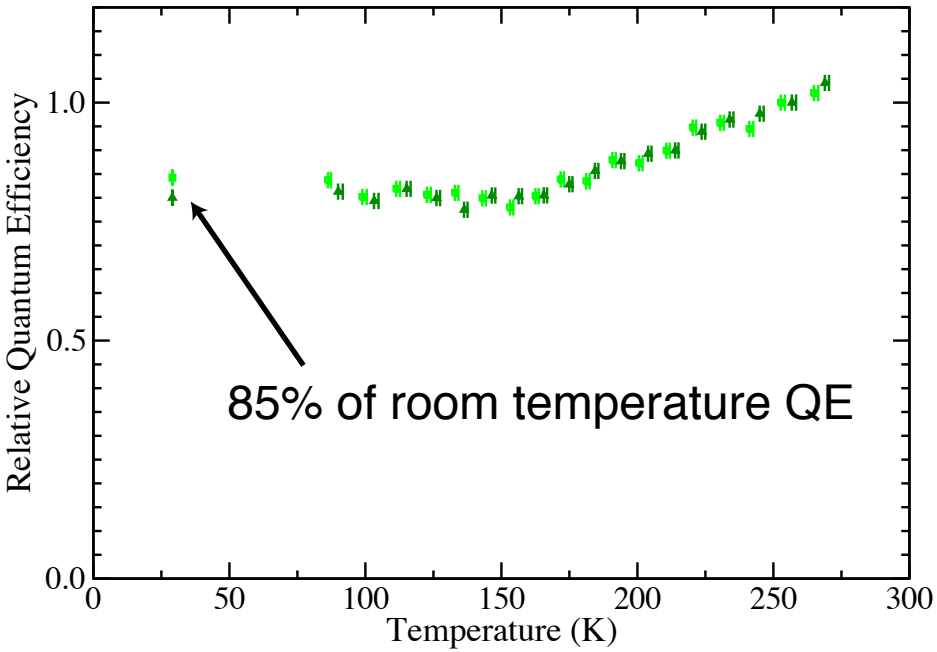

Counts
Total signal (pe)
0
200
400
600
800
1000
0
50
100
150
200


1.0
0.5
0.0
f_{prompt}
0
100
200
300
Total Area (pe)

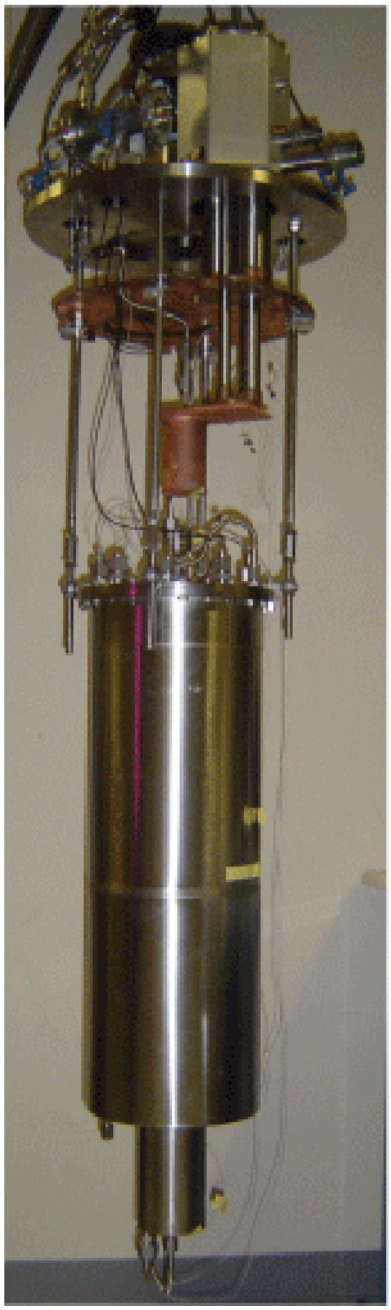

1.0
0.5
0.0
f_{prompt}
0
100
200
300
Total Area (pe)

PMT testing at 27 K





Micro-CLEAN



2 meters

Cooldown now beginning at Yale

Two 20-cm low-background PMTs

4 kg active mass of LAr or LNe

PMTs are immersed in cryogen

Cooled with pulse tube refrigerator

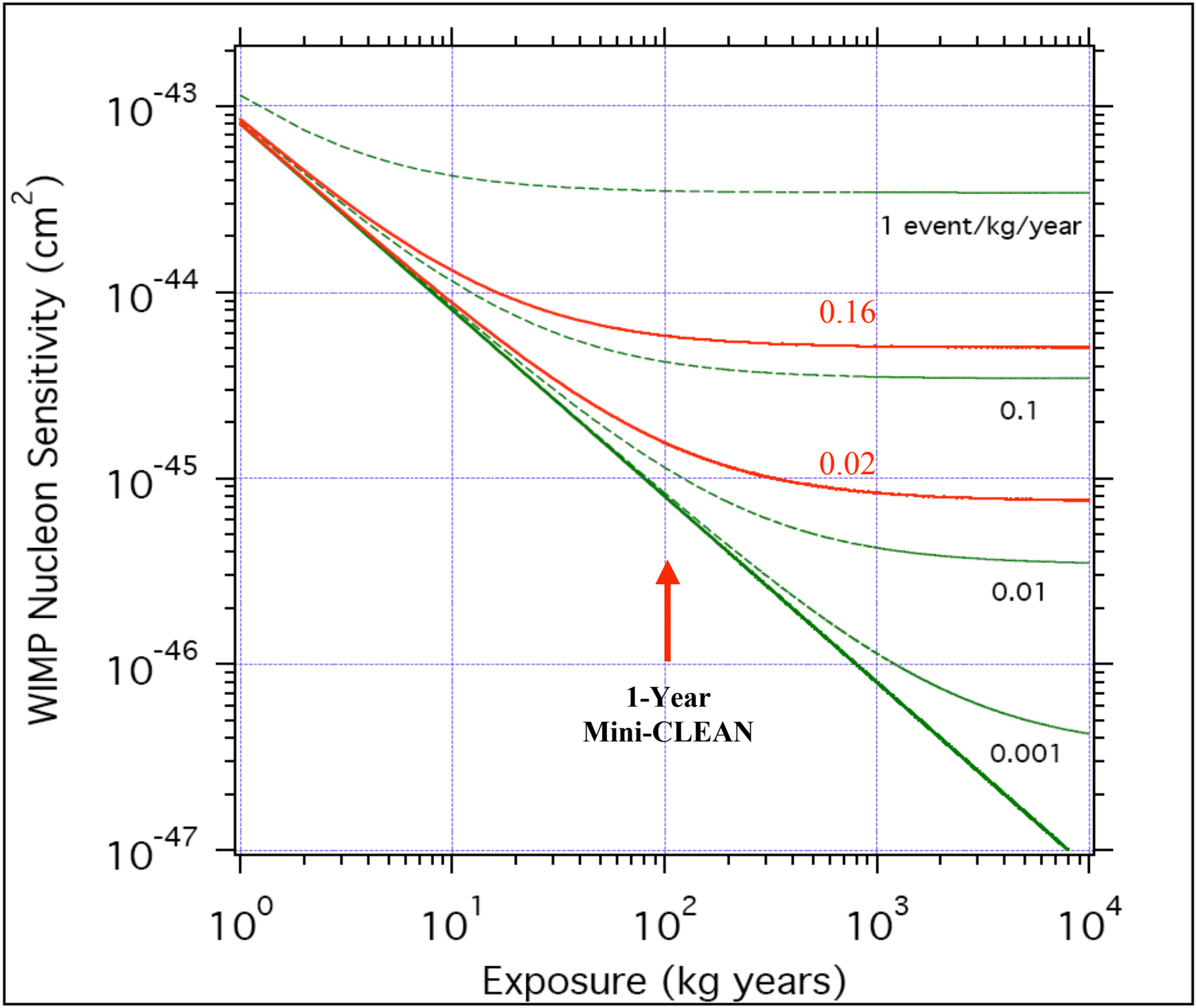
Goals:

1) Demonstration of 4 pe/keV

2) Testing of PMTs in LAr, LNe

3) Testing of electronics (Boston U)

4) Testing of pulse shape discrimination down to 10 keV


WIMP Nucleon Sensitivity (cm^2)
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^0
10^1
10^2
10^3
10^4
Exposure (kg years)
1 event/kg/year
0.16
0.1
0.02
0.01
0.001
1-Year
Mini-CLEAN

Mini-CLEAN Requirements

20 kW of electrical power, including 10 kW UPS

Water shielding tank, 20 feet in diameter

2 ton crane to add & extract scintillation vessel

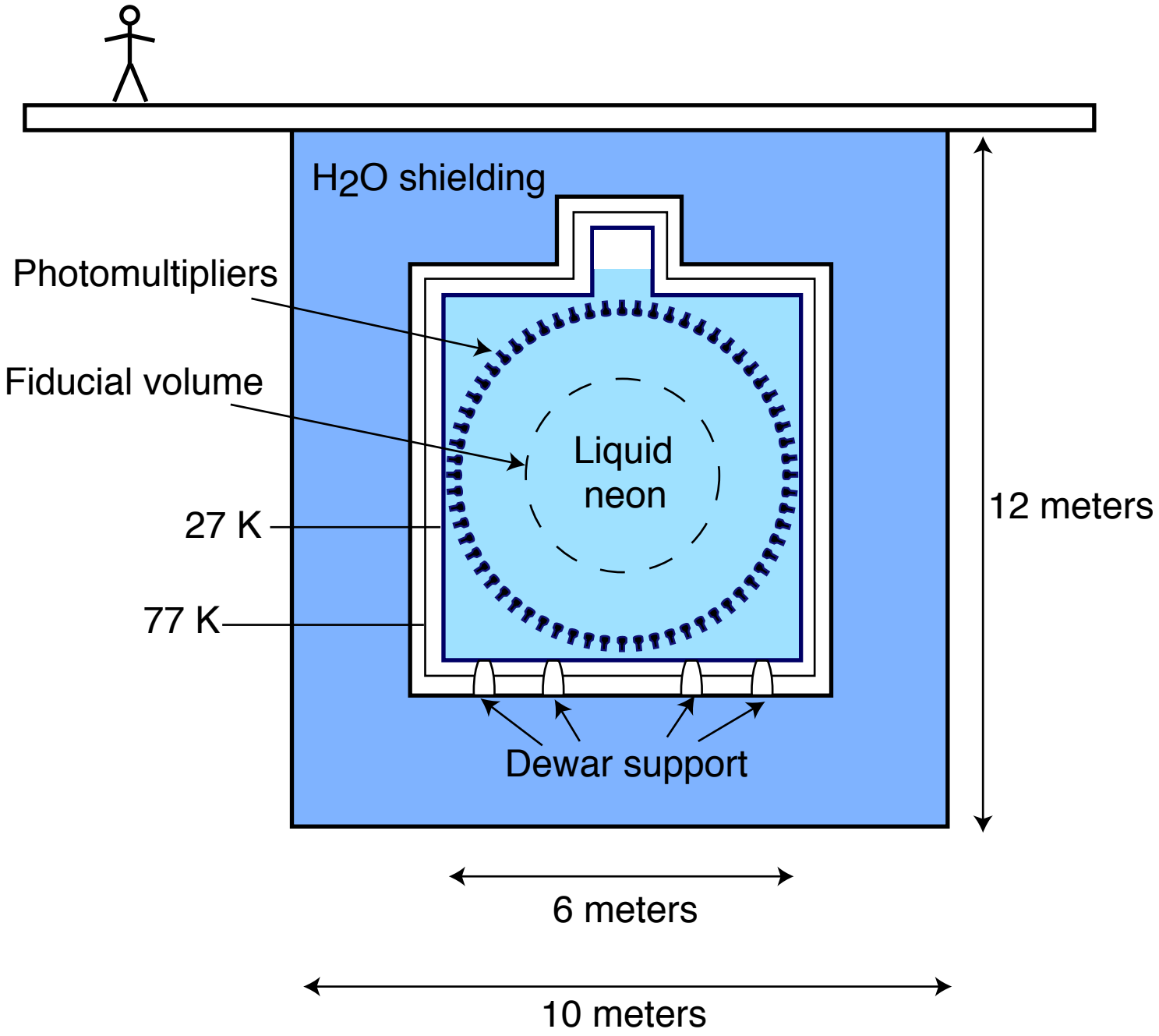
30 feet of height from the bottom of the tank to the bottom of the crane hook

1000 square feet of underground space for gas handling systems, neon storage, electronics, computers.

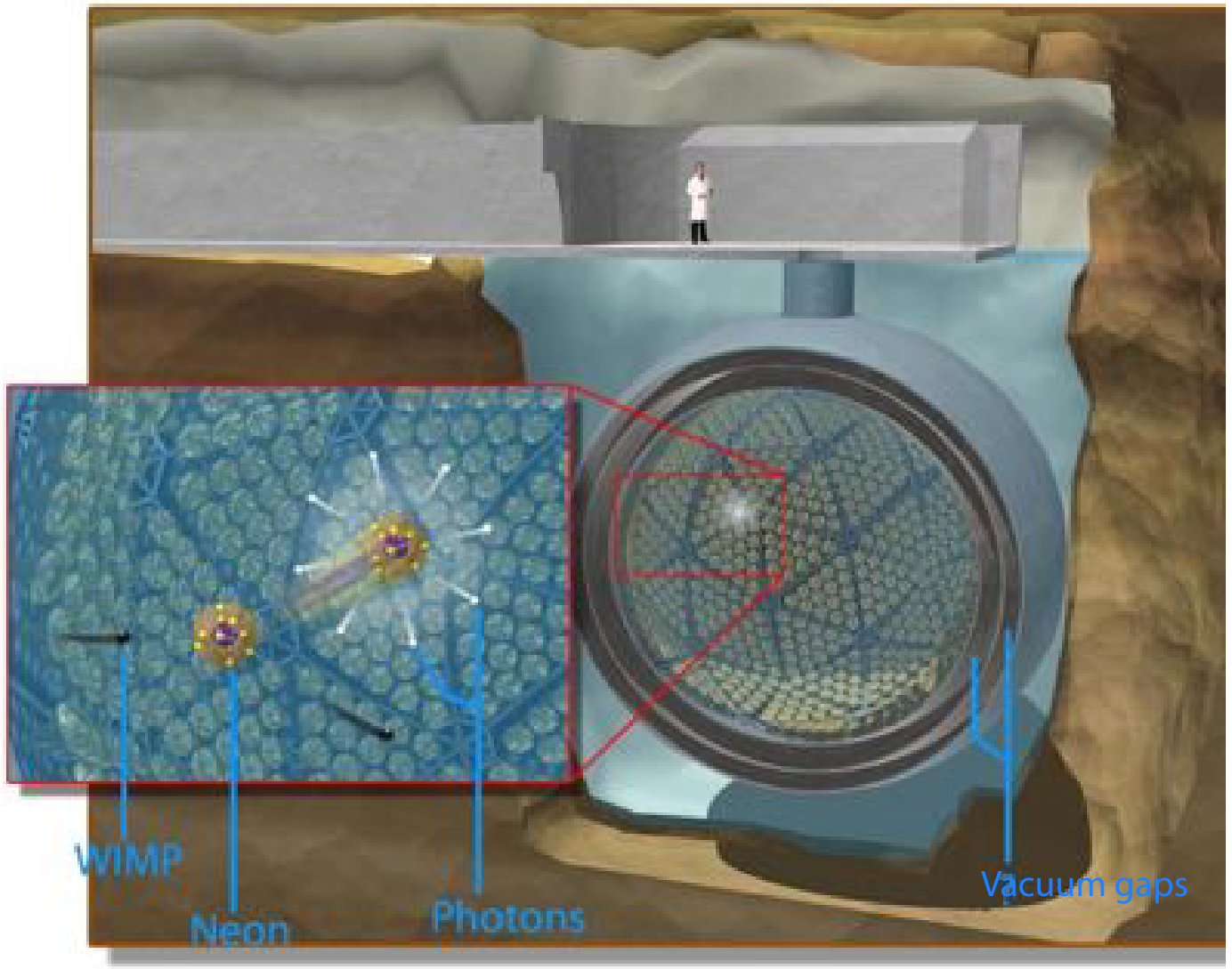
Neon will be brought underground in pressurized gas cylinders (10)

An office above ground

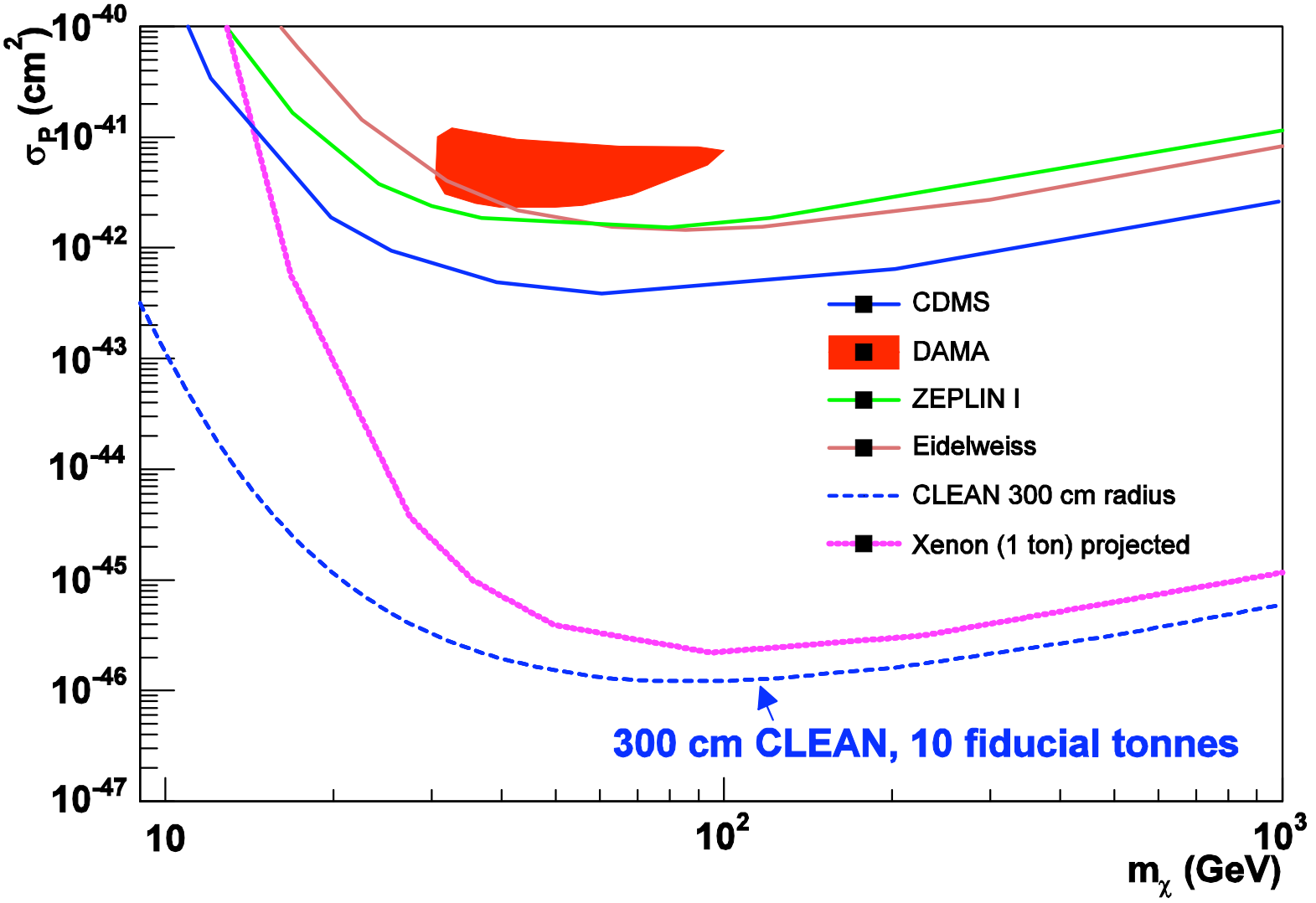
10-tonne CLEAN
5,000 neutrino events/year, assuming SSM, LMA



Artist's Rendition of CLEAN

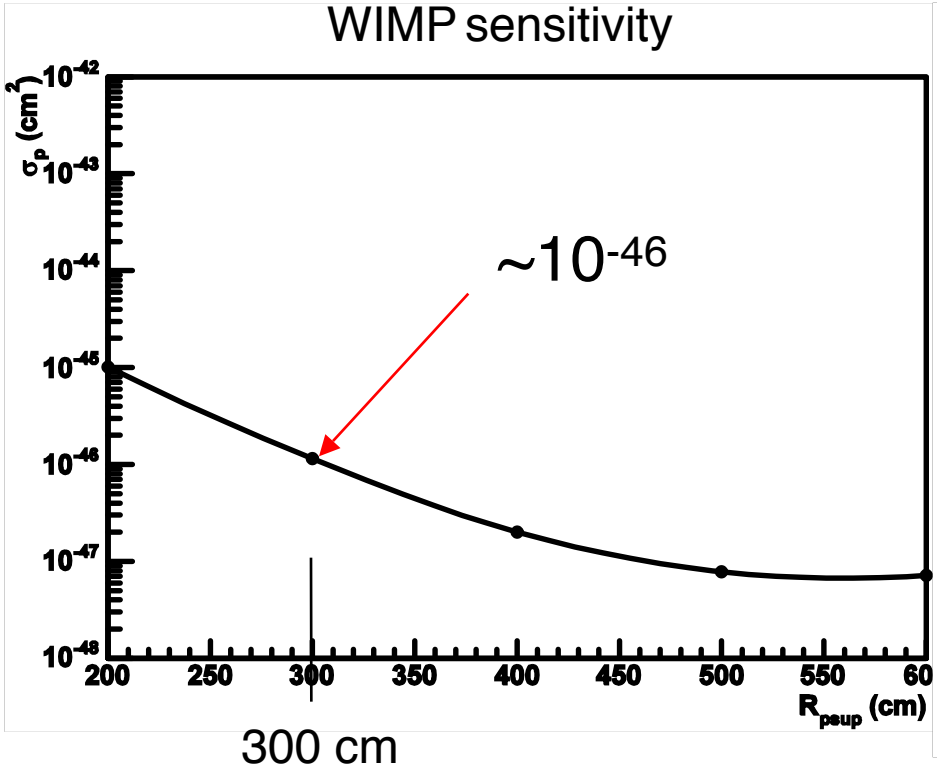


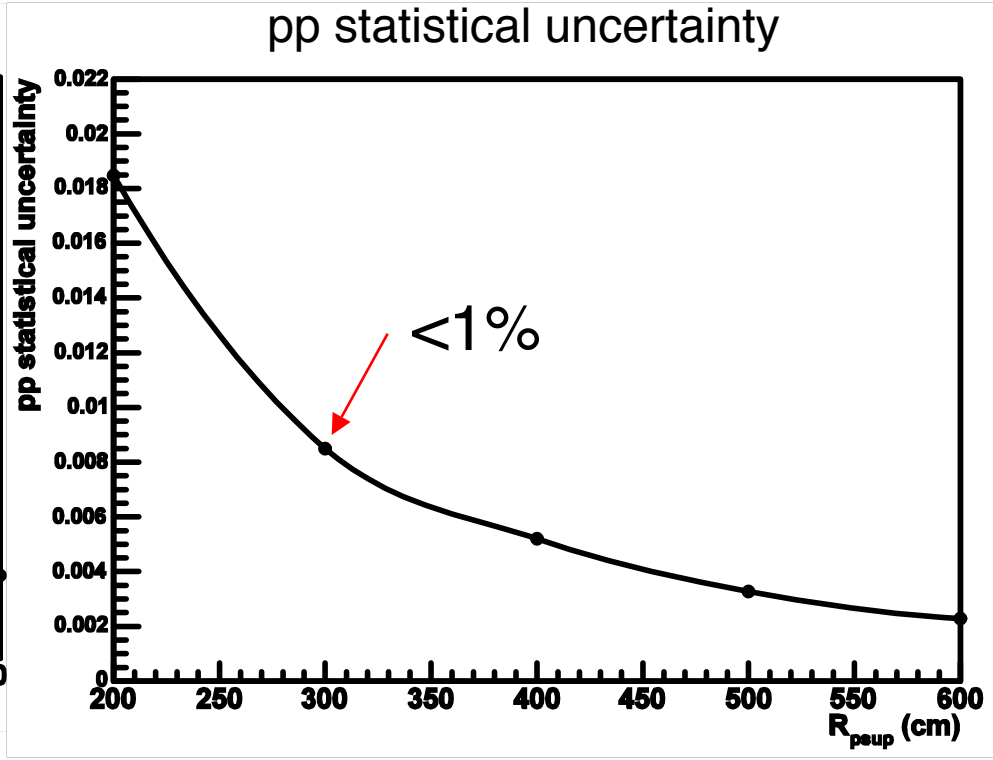
Dark matter sensitivity with Liquid Neon



Monte Carlo simulation: M. Boulay and A. Hime, nucl-ex/0410025

Simulations performed with GEANT4
15,000 photons/MeV
60 cm Rayleigh scattering length
75% PMT coverage, 15% QE
100% photon-to-photon wavelength shifter efficiency
Background dominated by (commercially available) PMT glass: 30 ppb U/Th, 60 ppm K





Summary

Completed R&D on gamma-nuclear recoil discrimination in both LNe and LAr and testing PMTs at low temperature.

A 4-kg prototype detector is now being tested.

Small version of CLEAN (mini-CLEAN) with 100 kg active mass will be highly sensitive to WIMPs. Can fill with either LAr or LNe.

Will build & test mini-CLEAN at Yale, 2006-2007.

Room-temperature shielding should be built in parallel. We do not yet have final plans for how or where to build this shielding. The large water tank proposed by R. Gaitskell and T. Shutt would fill this need.

The mini-CLEAN collaboration also has an LOI at SNOLAB, but final decision has not been made on th best site for the experiment.

Could bring mini-CLEAN underground in late 2007/early 2008.